Reprinted from *1998 Columbia Basin Agricultural Research Annual Report. Spec. Rpt. 989,* pp. 41-46, 1998
Oregon State University in cooperation with USDA-Agricultural Research Service, Pendleton, OR

OPTIMUM BIOSOLIDS APPLICATION RATES FOR SOFT WHITE WINTER WHEAT

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Biosolids (digested sewage sludge), a byproduct of municipal wastewater treatment, are an inexpensive source of nutrients and organic matter (Sullivan, 1998). Current economics make long-distance transport to central Oregon a viable option for large western Oregon wastewater treatment facilities (Sullivan et al., 1997). Biosolids transportation, land application, and site monitoring costs are currently paid by the wastewater treatment facilities.

The objectives of our research are to:

- Determine optimum biosolids application rates for dryland cropping
- Measure the availability of biosolids N relative to fertilizer N (anhydrous ammonia)
- Determine the residual soil fertility effects of a one-time biosolids application

Materials and Methods

The Unified Sewerage Agency (USA) of Washington County, Oregon supplied the anaerobically-digested, dewatered biosolids (17% dry matter; 83% water) used in our study. Each dry ton of biosolids contained an average of 89 lb organic N and 14 lb N ammonium-N.

This report covers results from one on-farm test site, located about 3 mi north of Moro on a Walla Walla silt loam soil (30–40 in average depth). The site was managed as a wheat-fallow rotation, with crop harvest in 1995 (before our study) and in 1997. Our cooperator (Pinkerton Bros.) performed routine tillage and crop management practices.

The field study included eight treatments replicated three times in a randomized complete block design. Individual plots measured 40 ft by 300 ft; grain yield was determined by harvesting a 27 ft combine swath from the center of each plot. Three rates of biosolids (low, medium, and high; 1.5, 2.4, and 4.5 dry ton/acre) were applied in the fall after crop harvest (6 Nov. 1995) and in the spring before the first fallow tillage (22 Apr. 1996). The biosolids application was compared to an anhydrous ammonia control (50 lb N/acre; applied 3 July 1996), and an unfertilized control. The biosolids application dates in our study represent the most feasible application times for biosolids in a wheat-fallow cropping system. Fallow tillage was delayed until May 1996 by controlling weeds with glyphosate. Soft-white club wheat *Triticum aestivum* L. 'Rohde' was seeded in October 1996.

We chose application rates of biosolids based on previous research in central Washington (Cogger et al., 1997). Washington trials in wheat-fallow systems (10–14 in annual precipitation) showed that a three dry ton/acre application of biosolids supplied more N than applying 50 lb N/acre as anhydrous ammonia.

Biosolids were applied via a rear-delivery manure spreader equipped with a hydraulic ram. The interval between application and the first fallow tillage was about six months for the fall application and about a month for the spring application. The pH of the biosolids was about 8.0, favoring rapid ammonia volatilization after application. Thus, most of the ammonium-N initially present in the biosolids (14 lb per dry ton) was probably volatilized before the first fallow tillage.

Soil and plant analyses were conducted via standard methods at the OSU Central Analytical Laboratory. We collected soil samples for analysis of ammonium-nitrogen + nitrate-nitrogen (NH_4-N + NO_3-N) in depth increments: 0–12 in, 12–24 in, and 24 + in to rock contact. For the 24+ in depth, we estimated an average depth of 6 in (24–30 in). Soil samples for other nutrients were collected to a depth of 12 in (fallow) and 6 in (postharvest).

Results and Discussion

Biosolids application date (fall vs. spring) did not affect yield response, crop nutrient concentrations, or soil N concentrations. Therefore, we present our measurements as a function of biosolids application rate only. Replications did not remove a significant amount of variation; therefore, we present data for individual field plots in Figures 1–3.

Optimum biosolids application rate

Grain yield and quality equivalent to that produced with anhydrous ammonia was produced with the medium rate of biosolids (2.4 dry ton/acre). Yield response to increasing biosolids rate was described by a plateau regression model (Figure 1a). Biosolids application did not affect thousand kernel weight (37 g/thousand), grain test weight (61 lb/bu), straw production (3500 lb/acre), or grain harvest index (43%). Grain N (1.6 to 1.7%) was equivalent for anhydrous ammonia and biosolids at the medium rate (Figure 1b). The high biosolids rate increased grain N to above 2.0%. Flag leaf N and S concentrations were also equivalent for anhydrous ammonia and the medium biosolids rate at three sampling dates (22 May, 4 Jun, and 10 Jun; head emergence, flowering; milk growth stages).

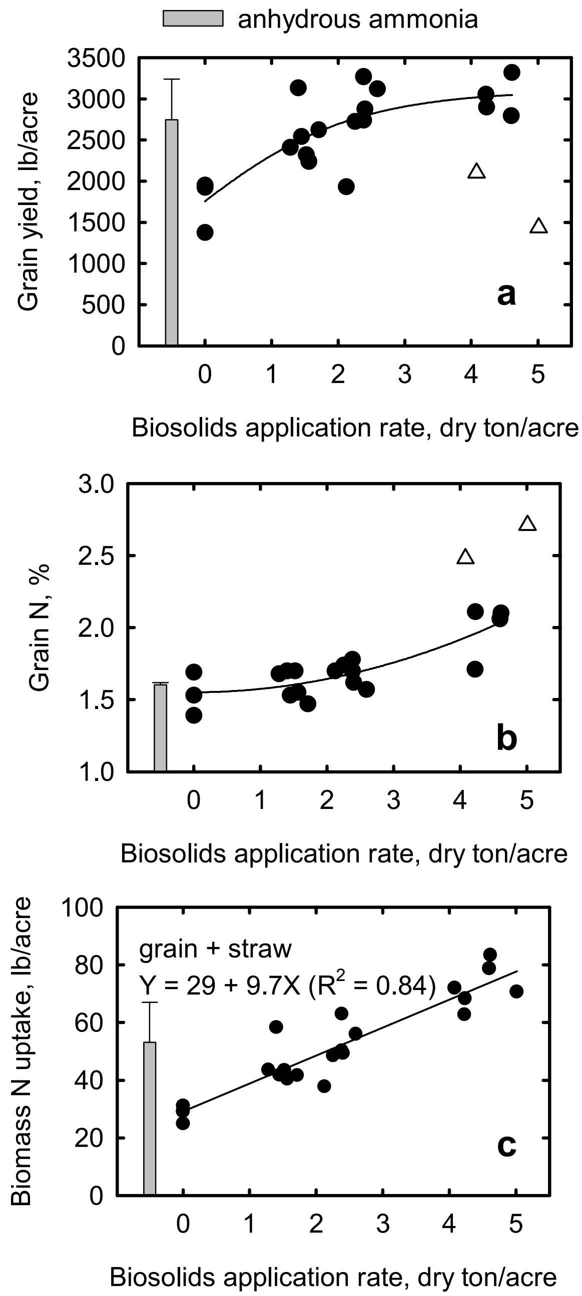

Figure 1. Anhydrous ammonia (50 lb N/acre) and biosolids effects on grain yield (a), grain N concentration (b), and biomass N uptake (c). Pinkerton Farm, Wasco County, 1997. Triangle symbols are data from shallow soil (12–20 in) with severe moisture stress during grain fill (excluded from regression lines).

Figure 2 shows the N and S concentrations for the flowering growth stage.

Two plots on shallow soil (12–24 in) with the high rate of biosolids had severe water stress during grain filling. These plots were omitted from the biosolids yield and grain N regression equations (triangle symbols in Figure 1a and 1b). The water stress caused by shallow soil in conjunction with high biosolids N supply on these plots produced low yields of shriveled grain (test weight 57–58 lb/bu).

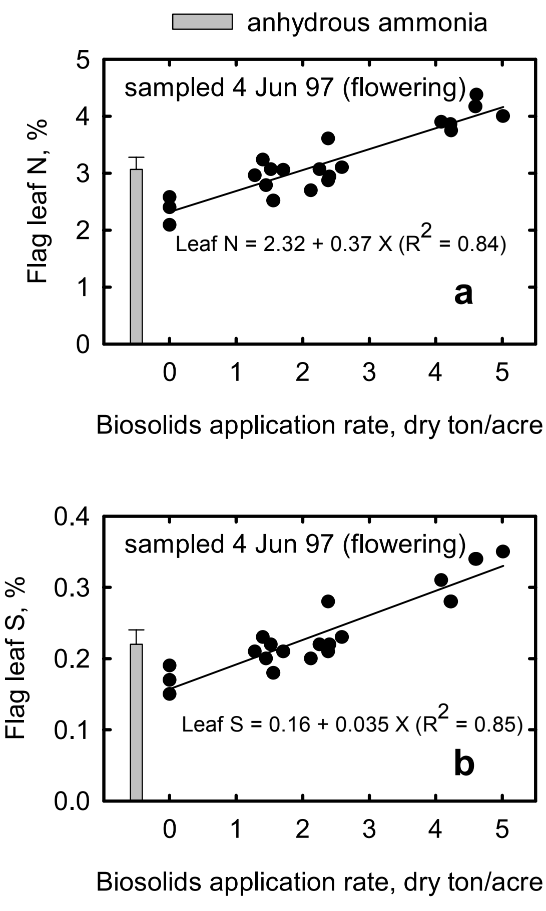

Figure 2. Anhydrous ammonia (50 lb N/acre) and biosolids effects on flag leaf N (a) and S (b). Pinkerton Farm, Wasco County, 1997.

Biomass N uptake (grain + straw) increased linearly with biosolids rate; it was equivalent to that produced with anhydrous ammonia at the medium biosolids rate (Figure 1c). Increased N uptake at the high biosolids rate was due to increased grain and straw N concentrations. Straw N was 0.3% with anhydrous ammonia or the medium biosolids rate; it increased to 0.5% at the high biosolids rate.

Available soil nitrogen

Biosolids application increased available soil N (NH_4-N + NO_3-N) during summer fallow (26 Jun. 96), in the spring of the crop year (2 Apr. 97) and after crop harvest (3 Sept. 97). We used the slope of the regression line for each sampling date to estimate the increase in available soil N because of biosolids application (Figure 3).

For the fallow sampling, biosolids increased available soil N by 14.2 lb/dry ton (Figure 3a). Most of the additional fallow N measured with biosolids application was recovered from the top 12 in. Apparently, ammonium-N from the fall application (6 Nov.) was not converted to leachable nitrate until the following spring. The fallow sample was taken before the anhydrous ammonia application.

For the spring (tillering) sampling, the additional available soil N recovered with biosolids application was 16.8 lb N/dry ton (Figure 3b). The above-average precipitation for winter 1996–97, coupled with excellent soil moisture at the end of the fallow (fall 1996), resulted in downward movement of nitrate. Spring soil samples showed the highest nitrate concentrations at the 24–30 in depth. Soil NH_4-N + NO_3-N recovered from the anhydrous ammonia treatment was 15 lb N/acre greater than for the unfertilized check, considerably less than the 50 lb N/acre applied. So, it’s likely that

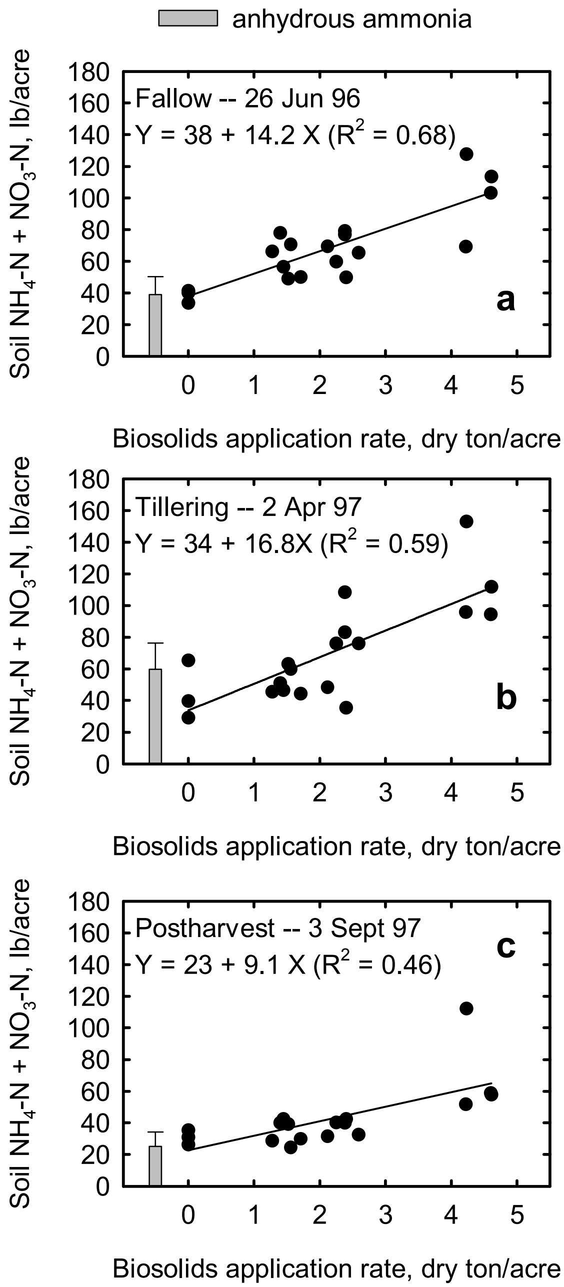

Figure 3. Soil ammonium + nitrate-N for 0–30 in depth with anhydrous ammonia (50 lb N/acre) and biosolids in fallow (a), in crop (b), and postharvest (c). Pinkerton Farm, Wasco County, 1996–97.

some of the available N from biosolids also moved below the sampling depth.

For postharvest sampling, the additional available soil N provided by biosolids was 9.1 lb N/dry ton. This residual N will be available to the next crop, provided it is not lost via leaching or denitrification. Additional available N will also be mineralized from the organic N supplied by biosolids during the next cropping cycle.

Availability of other nutrients

Similar grain yields were achieved with biosolids and with anhydrous ammonia, which supplied only N. Therefore, we conclude that the other nutrients supplied by biosolids did not increase grain yield during the first year after application. The other nutrients supplied by biosolids, however, could provide a benefit at sites with higher yield potential or for crops with higher nutrient demand (e.g., canola).

Sulfur. Biosolids provided small amounts of plant-available sulfate-S (1 to 3 lb S/dry ton) based on soil samples collected during summer fallow. Sulfur concentrations in wheat flag leaves (0.22%), straw (0.04%) and grain (0.11%) were the same for anhydrous ammonia and the medium rate of biosolids. Plant tissue N/S ratios remained at constant values (15:1) across all biosolids application rates (Figure 2), supporting our conclusion that S supply did not limit yield. Flag leaf N:S ratios of greater than 17:1 are usually observed in conjunction with S deficiency (Rasmussen, 1996). Postharvest sulfate-S soil samples showed no increase in extractable sulfate-S because of biosolids application.

Phosphorus. Biosolids did not increase P concentrations in flag leaves (0.20%), straw (0.03%) or grain (0.29%). Postharvest Bray-1 soil P (0–6 in) increased from 39 ppm without biosolids to 50 ppm with the high biosolids rate. The Bray P soil test calibration for winter wheat predicts a response to added P when concentrations are below 20 ppm (Marx et al., 1996), supporting our conclusion that biosolids P did not affect first-year wheat yields. The change in soil–test P reported here is small compared to that reported previously for Seattle area biosolids applied to dryland wheat in central Washington (Sullivan et al., 1995). It is also surprisingly small given the large amount of P applied (54 lb/dry ton). Apparently, much of the biosolids P was in insoluble forms that were not immediately available for plant uptake.

Zinc. Postharvest DTPA-extractable soil Zn increased from 0.4 ppm without biosolids to 0.8 ppm with the high biosolids rate. Plant tissue Zn in flag leaves (14 ppm), straw (3 ppm), and grain (16 ppm) were the same for the medium rate of biosolids and anhydrous ammonia. Soil and plant tissue Zn concentrations reported here are near or below suggested deficiency levels for Zn (Marx et al., 1996; Lindsay and Norvell, 1978).

Other nutrients. Biosolids application did not change extractable soil Ca, Mg, K, Na, Fe, and Mn. Small increases in hot-water extractable B (+ 0.1 ppm) and DTPA-extractable Cu (+ 0.6 ppm) were measured with the high biosolids rate.

Soil pH and soluble salts. Fallow samples (Jun. 1996) showed that the high biosolids rate reduced soil pH from 6.5 to 6.2 and increased soluble salt conductivity from 0.2 to 0.5 mmhos/cm. This effect was temporary. Postharvest samples (Sept. 1997) showed that biosolids application did not affect soil pH (6.4), SMP buffer pH (6.9) or soluble salt conductivity (0.3 mmhos/cm).

Summary and Conclusions

A biosolids application rate of approximately 2.4 dry ton/acre produced grain yield and plant N concentrations equivalent to those produced with application of 50 lb N/acre as anhydrous ammonia. Biosolids applied in the fall after crop harvest or in the spring of the fallow year performed similarly.

Biosolids provided at least 19 lb of available N per dry ton during the first cropping cycle, based on data for grain + straw N uptake (Figure 1c) and postharvest soil NH_4-N + NO_3-N (Figure 2c). This estimate of biosolids N availability is conservative; it does not include nitrate-N that moved below our soil sampling depth (30 in), or ammonium-N volatilized shortly after application.

We did not observe a yield response to the other nutrients supplied by biosolids. Biosolids increased the availability of P, Zn, Cu, and B as determined by postharvest soil testing.

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